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Review of the membrane and bipolar plates materials for conventional and unitized regenerative fuel cells

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ABSTRACT

Fuel cell or hydrogen systems offer the potential for clean, reliable and on-site energy generation. This article review current literature with the objective of identifying the latest development in membrane and bipolar plates for the conventional fuel cell and unitized regenerative fuel cell (URFC). The result shows that the choice of both the bipolar plates and the catalysts for URFC electrodes is a delicate task, for bipolar plate the corrosion in the oxygen side will be the major problem and for the electrodes a very good candidate for fuel cell mode will not function well in the electrolyser mode and therefore it is suggested that a compromise should be considered. It is recommended that aluminum, titanium or for best results titanium with a gold-coated layer is a suitable candidate as the bipolar plate and Pt/IrO_X or Pt/Ru is suitable for an oxygen side catalyst in the URFC. For the conventional fuel cell the task is more easer because the corrosion problem is no more effective and thus the main goals for most of the studies was to concentrate on bipolar plate cost reduction, increase electrical conduction and reducing the platinum loading rate for catalyst.

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1. Introduction

Fuel cell based power plants offer one of the most lucrative possibilities for future power generation and the fuel cell is also found to be potentially more efficient than the conventional plants since the fuel reacts electrochemically instead of combustion. In this way there is far less air, thermal, and noise pollution issues to be considered. A conventional fuel cell is an electrochemical device that produces electricity by separating the fuel (generally hydrogen gas) via a catalyst. The protons flow through a membrane and combine with oxygen to regenerate water with the help of the catalyst used while the electrons flow from the anode to the cathode to create electricity.

An electrolyser operates reversely to the fuel cell which splits water into hydrogen and oxygen by the power supplied. To make a hydrogen system self dependant energy source, an electrolyser should exist to generate gases which then be consume to generate power through the fuel cell. For some applications a specific weight (power per unit weight) is an important issue to be considered,

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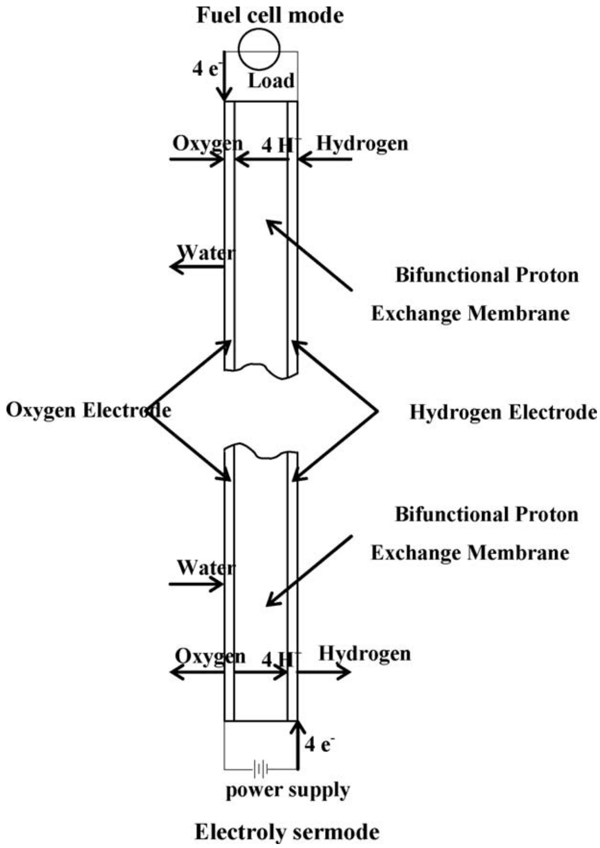

Fig. 1. Electrochemical reaction in the URFC.

thus researches succeed in getting one cell to function as electrolyser and fuel cell in one cell at different modes. This cell is known as a unitized regenerative fuel cell (URFC). The URFC works logically in the electrolyser mode first to store hydrogen and then use it in the fuel cell mode, thus the URFC behaves like a battery as a self independent power source but in contrast to the battery system, the URFC is unaffected by the depth of the discharge or length of the cycle duration. In the URFC, energy and power are not linked i.e. the cell is sized for power but the storage tank is sized for energy [1]. A diagram of the electrochemical reaction that occurs in the proton exchange membrane (PEM) of the URFC is shown in Fig. 1.

The objective of this study is to compare the materials used in a conventional fuel cell and the URFC. For that purpose a review of the latest development in the materials used for the bipolar plate and the development in the membrane electrode assembly (MEA) for both the conventional fuel cell and URFC was carried out.

2. Bipolar plate for conventional fuel cell

Flow channels are conveniently machined into a bipolar plate or field plate to allow a high electronic, good thermal conductivity and stability in a chemical environment inside a fuel cell [2]. In a fuel cell stack, each bipolar plate supports two adjacent cells and the bipolar plate is known to have five typical functions: (1) to distribute the fuel and its oxidants within the cell (2) to facilitate water management within the cell (3) to separate individual cells in the stack (4) to transport currents away from the cell and (5) to facilitate heat management [3]. The sketch of a bipolar plate is shown in Fig. 2.

The main target for all researchers is to focus on the bipolar cost reduction, increase the electric conductivity, decrease the weight and increase the corrosion resistance. Generally most of the bipolar plates used in conventional fuel cells are either made of graphite, stainless steel or of other metallic materials. In this article, we would like to review the latest development of each material individually.

2.1. Stainless steel

Stainless steel is widely used as a bipolar plate for fuel cell application that is due to its chemical stability during the chemical reaction and also its ability to conduct electric however, its corrosion resistivity is low unless treated or coated with some other material to enhance its corrosion resistivity. Hornung and Kappelt [4] examined the suitability of economical corrosion resistance of Fe-based alloys (FeBs) in the construction of bipolar plates. The results indicate that most of the (FeBs) exhibit a characteristic comparable to that of the Ni-based alloy. Makkus et al. [5] tested several stainless steel bipolar plates and found that using stainless steel as a flow plate at the anode side of a solid polymer fuel cell (SPFC) results in a higher contamination of the MEA as compared to a stainless steel flow plate that is used on the cathode side. Davies et al. [6] tested three stainless steel alloys

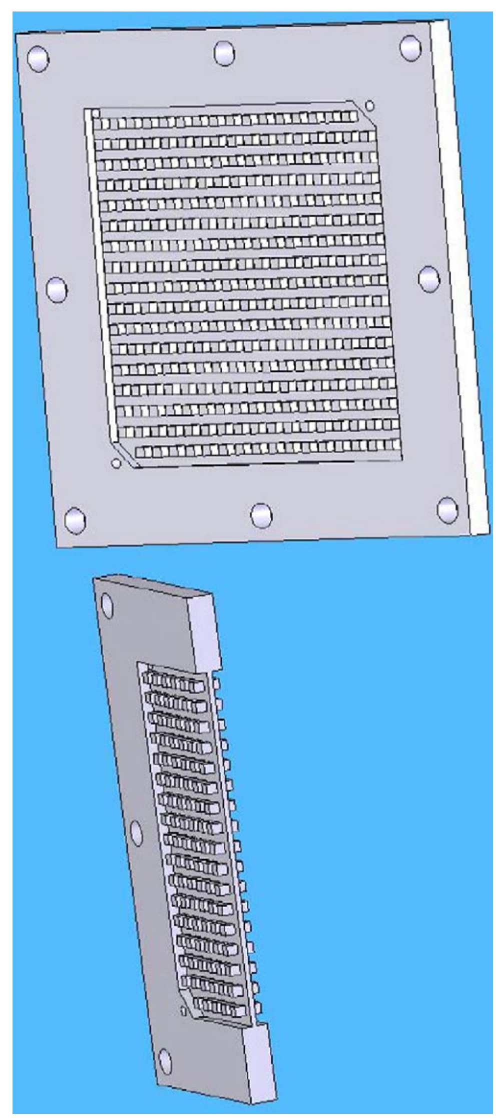

Fig. 2. Bipolar plate used in PEM fuel cell stack.